

Inflow and Hydrology

Freshwater Inflows to Galveston Bay

*Ruben S. Solis and David A. Brock
Texas Water Development Board*

The Texas Water Development Board (TWDB) has performed environmental studies of six estuaries including Galveston Bay (Trinity-San Jacinto Estuary) under its Bays and Estuaries Program. A fundamental requirement for all of the environmental studies is the quantitative estimation of terrestrial freshwater inflows into the bay. Freshwater inflows provide nutrients and sediment to the bay and mix with saline Gulf waters to provide the environment required by estuarine species.

Freshwater inflows for the period from 1941 to 1976 were estimated in previous studies in the early 1980s (Texas Department of Water Resources, 1980a; 1980b; 1981a; 1981b; 1981c; 1983). This database of inflows was extended through 1987 in the current set of studies. Data sources used in compiling these hydrological databases include the U. S. Geological Survey (USGS) stream gage network, National Weather Service meteorological stations, and the Texas Water Commission's return flow and diversion database. Inflows from both gaged and ungaged areas are included in the study. Runoff volumes from ungaged watersheds, areas nearest the bay and below the lowest USGS gages, were calculated with a rainfall/runoff model developed by the TWDB. Ungaged runoff was adjusted for return flows and diversions to estimate freshwater inflow from ungaged areas.

For the study period from 1941 to 1987, annual freshwater inflows to Galveston Bay averaged 10.06 million ac-ft. This represents roughly 5.1 times the volume of the Trinity-San Jacinto Estuary. Of this, roughly 68% (7.48 million ac-ft/year) originates in gaged watersheds (areas above USGS stream gages), while the remaining 32% (3.17 million ac-ft/year) drains from ungaged areas. The Trinity River is Galveston Bay's single largest contributor of freshwater, providing an average of 51% (5.34 million ac-ft) of the total freshwater inflow annually from 1941-1987.

On a seasonal basis, the largest freshwater inflows occur in May (1.47 million ac-ft), while the smallest occur in August (0.37 million ac-ft). On average, greatest inflows occur in the winter and spring (December through June), while inflows are lowest in the summer and fall (July through November).

A non-parametric trend analysis applied to monthly inflows for the twenty year period 1968 to 1987 indicates a statistically significant increase ($p < 0.05$) in inflows to Galveston Bay, averaging 0.52%/year. This trend is absent in Trinity River inflows, suggesting that the increase is the result of increased urbanization and industrialization in and near Houston.

On the Texas coast, inflows to Galveston Bay are second only to those for Sabine Lake, which average 13.03 million ac-ft/year.

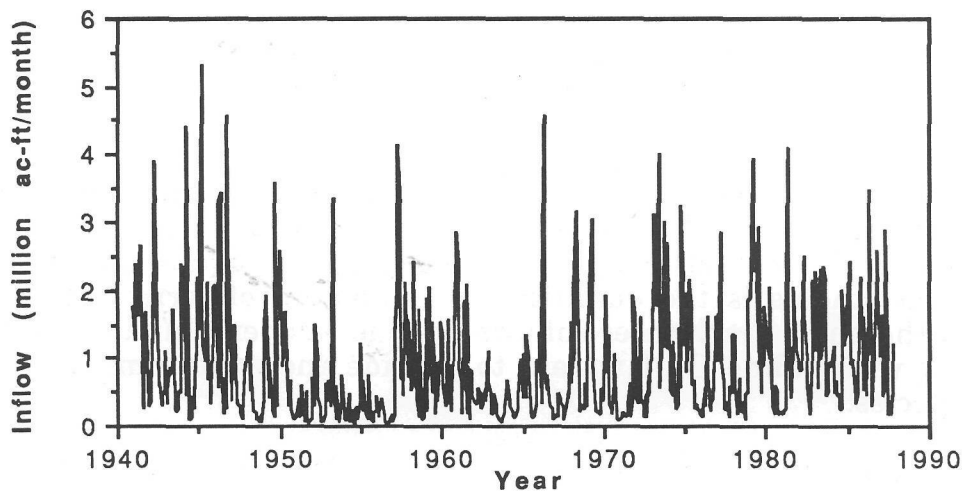


Figure 1. Freshwater inflows to Galveston Bay, 1941-1987.

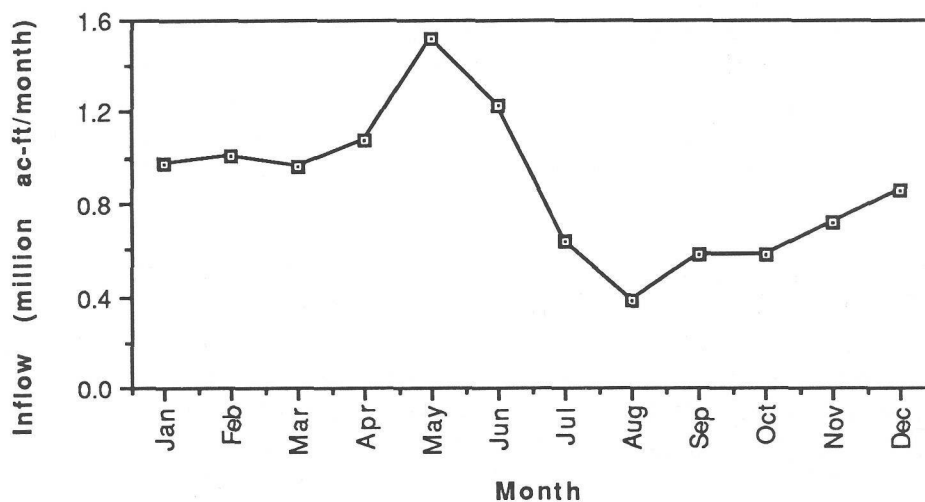


Figure 2. Average Monthly inflows to Galveston Bay, 1941-1987.

Additional TWDB Studies

The TWDB performed a three-day intensive inflow field study in May 1990 covering the entire 600 square miles of the Trinity-San Jacinto Estuary. Water elevation, velocity, and salinity data were collected during this effort. These data have been compiled and analyzed and are being used in the calibration of the Board's 2-D hydrodynamic and conservative transport model.

Texans are concerned with the management of nutrient loading to the estuaries, particularly Galveston Bay. Galveston Bay receives an average of 26.8 g N per m² per year, 6.25 g P per m² per year, and 121 g C per m² per year (as total organic

carbon) through its terrestrial drainage and rainfall. In this context it is desirable to understand the relative importance of freshwater inflows as nutrient sources. This requires knowledge of other sources of nutrient inputs and avenues of nutrient loss from the bay. The comparison of sources and sinks is efficiently addressed through the computation of nutrient budgets. Work is underway to develop budgets for nitrogen, phosphorus, and organic carbon for Galveston Bay. Sources of these nutrients include gaged inflows, ungaged rainfall runoff, municipal return flows, direct atmospheric deposition, and tidal exchanges. Losses to the bay include export to the Gulf of Mexico, fisheries harvest, burial, and (for nitrogen) denitrification. Nutrient loading from terrestrial drainages is estimated from water quality monitoring data from streams and discharges, together with USGS stream flow data and results of simulations of rainfall runoff. Exchange of the bay with the Gulf is complex and based in part on dynamics of tidal entrainment which are not well understood. Results of computer hydraulic simulation provide a reasonable approach to this exchange. Results from San Antonio Bay suggest that biogeochemical processes may be significant nutrient sinks in Texas estuaries. More information is needed for the rates of these processes in Galveston Bay.

Literature Cited

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Next Generation Water Level Measurement System for Galveston Bay

*Gary A. Jeffress and Richard R. Phelps
Conrad Blucher Institute for Surveying and Science,
Corpus Christi State University*

The Conrad Blucher Institute for Surveying and Science has installed two Next Generation Water Level Measurement Systems (NGWLMS) in Galveston Bay. One system is located adjacent to the southern shoreline of Christmas Bay; the second system is located adjacent to the northern shoreline of Clear Lake. These two systems provide near real-time water level data for Galveston Bay. The systems have been installed so as to comply with the NGWLMS Site Design, Preparation, and Installation Manual, produced by the National Oceanic and Atmospheric Administration (NOAA).

The NGWLMS uses an air acoustic water level sensor (Aquatrak Model 3000). The sensor uses a time-of-travel technique to measure an acoustic pulse which is reflected from the water surface. The system is self-calibrating to account for variations in air density and has a resolution of ± 0.01 ft. The acoustic soundings occur within a one-half inch diameter sounding tube. The sounding tube is located within a six-inch diameter protective well which allows water to enter via eight orifices, each one-half inch in diameter, located at the bottom of the protective well.

The NGWLMS is controlled by a Sutron 9000 Remote Terminal Unit (RTU) which is a small computer that interfaces data acquisition, data storage, and communications. The primary mode of data communication is via a Geostationary Operational Environmental Satellite (GOES). Water level data is transmitted to the satellite every three hours. The data forms part of NOAA's NGWLMS data base and can be accessed via telephone or mailing list.

The systems use very little power and can operate using external batteries and solar cells for charging the batteries. The system requires an average of one watt for normal operation. Water level data is acquired every six minutes. Since installation in October 1990, the systems have close to 100% data capture records. Any missing data has been due to interruptions for system checking.

The two Galveston NGWLMS systems are each connected to five bench marks located at each site. Both sites have assumed datums which are presently not connected. A future component of the project will be to connect these two datums to a common datum known as the Blucher Datum. The Global Positioning System (GPS) will be used to connect the Galveston Bay sites to the Blucher Datum. Seven sites in the Corpus Christi area have been connected using GPS with very encouraging results.

The water level data will provide tidal data for the mean higher high water level. This level indicates the water-land intersection forming the mean higher high water line. This line indicates the location of the property boundary between the

State of Texas owned tide-lands and privately owned up-lands.

Presently, the systems also provide data on air temperature and water temperature. The systems are capable of recording up to sixteen environmental parameters. This facility will reduce the cost of additional environmental data for Galveston Bay that may be required in the future.

The two NGWLMSs in Galveston form part of twenty-three sites along the South Texas coast, known as the Blucher Institute Water Level Observation Network (BIWLON). The primary purpose of BIWLON is the measuring, collecting, analyzing, and disseminating water level data.

Characteristics of Hydrographic Data in Galveston Bay

F. C. Schlemmer, II
Texas A&M University at Galveston

Hydrographic data contained in two data archives of the State of Texas, the Statewide Monitoring Network (SMN) and the Coastal Data Set (CDS) were analyzed for their temporal and spatial distributions. The impetus for this study was to determine what data were available to estimate the temporal and spatial scales of property distributions and variabilities in Galveston Bay. This information would be necessary for design of any process studies of the waters within the bay. The station patterns found in the SMN consisted of about 28 stations concentrated in Trinity and Upper Galveston Bays, with none located in Lower Galveston Bay. Some of the monitoring sites were sampled infrequently. The 92 CDS stations were positioned along lines running roughly perpendicular to the axes of the secondary bays. The station sites were concentrated in Trinity Bay and Upper Galveston Bay with sparse sampling of Lower Galveston Bay, East Bay and West Bay. Many of the sites were sampled less than ten times over the almost thirty years represented by the data sets.

The two data sets were combined in a single data base which could be manipulated by computer. Data which were identified by codes in the original data sets as questionable or below/above detection limits were eliminated. The remaining data were sorted by season into one-minute squares for enumeration so that the data density of the various parameters could be determined. With respect to station distribution, summer had the greatest number of stations and the most complete coverage with significant decreases in numbers of stations and coverages in other seasons. Large areas of all secondary bays are unsampled or sampled seldom during the period. At the 1790 total stations (through 1987) in Galveston Bay (excluding West Bay), temperature was sampled most with 1597 stations having at least one observation, followed in order with dissolved oxygen, salinity, and pH and organic carbon with 1547, 1489, 1170, and 928 observations respectively. In West Bay, 452 total stations were sampled with the same five properties being sampled at about the same percentages as in Galveston Bay. The frequency of sampling of other chemical parameters dropped off rapidly. The coverages of total observations of temperature, salinity, dissolved oxygen and pH were fair in Upper Galveston Bay and Trinity Bay. Sampling in Lower Galveston Bay was sparse for these properties. Sampling for many other chemical properties was quite sparse even in Upper Galveston and Trinity Bays and extremely sparse to non-existent in Lower Galveston and East Bays.

Based on this study, considerably more data on property distributions within Galveston Bay will be required before studies providing even a basic understanding of processes can be designed.